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CODE OF PRACTICE FOR DESIGN OF TUNNELS CONVEYING WATER
PART III HYDRAULIC DESIGN
(First Revision)

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CODE OF PRACTICE FOR DESIGN OF TUNNELS CONVEYING WATER
PART III HYDRAULIC DESIGN
(First Revision)

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Indian Standard

CODE OF PRACTICE FOR DESIGN OF TUNNELS CONVEYING WATER

PART III HYDRAULIC DESIGN

(First Revision)

0. FOREWORD

0.1 This Indian Standard (Part III) (First Revision) was adopted by the Indian Standards Institution on 24 July 1976, after the draft finalized by the Water Conductor Systems Sectional Committee had been approved by the Civil Engineering Division Council.

0.2 The 'Indian Standard Code of practice for design of tunnels conveying water : Part III Hydraulic design' was first published in 1968. This revision has been taken up with a view to keeping abreast with the technological developments that have taken place in the field of tunnel design and construction. With the confidence gained in the construction of a large number of tunnels and the availability of concretes of higher strengths in the country, the provisions of the code have been recommended for adoption for tunnels carrying water at velocities up to 8 m/s without need for model studies. In keeping with the practice, provision for limiting instant velocity during surge oscillations has been deleted.

0.3 This standard has been published in parts. Other parts of the standard are as follows:

Part I-1975	General design
Part II-1976	Geometric design (*first revision*)
Part IV-1971	Structural design of concrete lining in rock
Part V-1972	Structural design of concrete lining in soft strata and soil
Part VI-1971	Tunnel supports
Part VII-1975	Structural design of steel lining

0.3.1 This part covers recommendations in regard to the hydraulic design of tunnels conveying water. These recommendations may be used for tunnels carrying water at velocities up to 8 m/s. For tunnels carrying water at velocities more than 8 m/s the design based on these recommendations may have to be corroborated by hydraulic model studies.

0.4 This code of practice represents standard of good practice and, therefore, takes the form of recommendation.

0.5 In the formulation of this standard due weightage has been given to international co-ordination among the standards and practices prevailing in different countries in addition to relating it to the practices in the field in this country. This has been met by referring to various publications including the following:

United States of America. Department of the Interior and Bureau of Reclamation. Design of small dams. Government Printing Office, Washington.

United States of America. Department of the Interior and Bureau of Reclamation. Engineering monograph No. 7, friction factors for large conduits flowing full. Government Printing Office, Washington.

Brown (JG), Ed. Hydro-Electric Engineering Practice, Vol I. Blackie & Son Ltd, Glasgow (by permission of the publisher).

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1. SCOPE

1.1 This standard (Part III) covers the hydraulic design of tunnels conveying water under pressure or under free flow conditions. This does not, however, cover the hydraulic design of other tunnel structures.

2. GENERAL CONSIDERATIONS

2.1 General — For the hydraulic design, in most cases hydraulic gradient shall be required. However, in addition to hydraulic gradient in certain locations, energy gradient, principles of momentum, transient conditions like water hammer, surges, etc, shall have to be considered. Where air is likely to be entrained because of high velocities, its effect due to bulking should be considered. Due consideration shall be given to maximum and minimum levels at the head and tail end.

2.1.1 The factors which combine to determine the nature of flow in a tunnel include such variables as pressure head, slope, size, shape, length, surface roughness of the tunnel, and the inlet and outlet shapes. The combined effect of these factors determines the location of control which in turn determines the discharge characteristics of the tunnel. In case of free flowing tunnels proper aeration shall be ensured. The tunnel shall be so designed that pulsating conditions are minimised. In the calculation of flow, expected variations in the friction factor shall be considered.

2.2 Obligatory Levels of Tunnel — In case of a pressure tunnel the depth of intake shall be such that no air is sucked in under any condition. The location of outlet of a tunnel shall be such that the entry of air would not adversely affect tunnel operation and safety provided that sufficient precautions for preventing air locks are taken (*see* **6**).

2.2.1 All tunnels should preferably have a positive gradient in the direction of flow, since they may have to be emptied and drained from time to time

for the purpose of inspection and maintenance. However, it may be borne in mind that in a well designed and constructed tunnel there would be only a little need of maintenance. Gradients and depth shall be such that under fluctuating conditions, including transient conditions, there shall be no possibility of air locks.

2.3 Cross Section — The geometric design of various sections usually adopted for tunnels is covered in IS : 4880 (Part II)-1976*.

2.3.1 Area of cross section of a tunnel shall be of sufficient size to carry the maximum required flow on the head available and in addition shall conform to construction requirements.

2.3.1.1 Tunnel dimensions and shape should be decided on the basis of economic studies so as to obtain a most economical section. The following should be taken into account:

a) Velocity requirements,
b) Loss due to tunnel friction,
c) Interest charges on capital cost of tunnel,
d) Annual maintenance charges,
e) Whether lined or unlined, and
f) Cost of gates and their hoists.

2.3.1.2 The tunnel diameter determined as a result of economic studies should be examined from practical considerations, such as space requirements for the excavating equipment and the section may be modified if necessary, based on the above considerations. A minimum height of 2 m is necessary. For mechanized handling of excavated material a minimum section of $2\cdot5 \times 2\cdot5$ m is required.

NOTE — In sound rock the unit cost of excavation decreases as the diameter increases to a point that permits the use of full sized shovel equipment, say up to 10 m in diameter. In weak rock the unit cost may increase as the size increases owing to extra cost of supports.

2.4 Cavitation — Design shall be such that negative pressures are avoided. To make sure that cavitation is avoided and to allow for uncertainties, the residual positive pressure shall not be less than 3 m of water head in concrete lined tunnels.

2.4.1 The recommended limiting sub-atmospheric pressures, based on probable minimum atmospheric pressures at different elevations above sea level, are indicated in Fig. 1.

NOTE — In locations which are susceptible to effects of cavitation such as downstream of gate slot, where there is a change of grade in high velocity flow, etc, steel lining may be considered.

3. TRANSITION SHAPES

3.1 From the tunnel section, either entry into or exit from the tunnel requires transition to reduce the head losses to a minimum and to avoid cavitation. The length and shape of the transition depends upon the velocity and flow

*Code of practice for design of tunnels conveying water: Part II Geometric design (*first revision*).

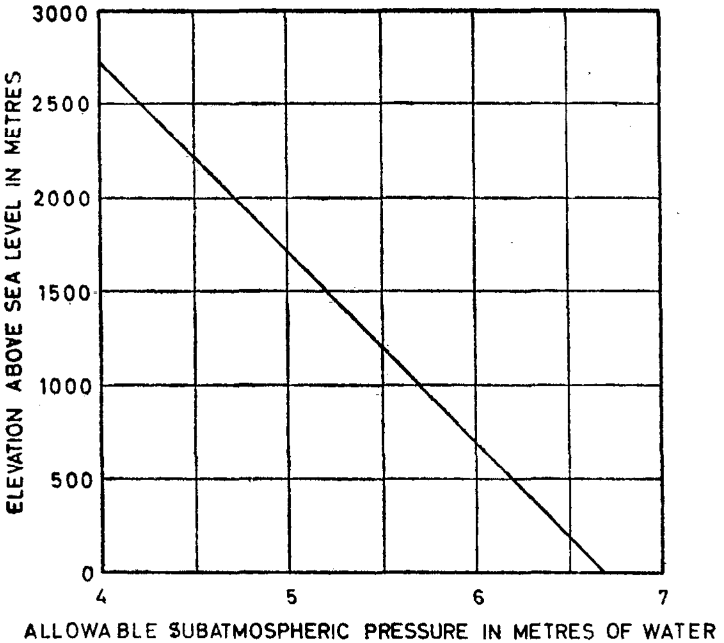

FIG. 1 ALLOWABLE SUBATMOSPHERIC PRESSURES FOR VARIOUS ELEVATIONS ABOVE SEA LEVEL

conditions prevailing in the tunnel, economics, construction limitations, etc. It is recommended that hydraulic model studies are conducted to determine an efficient and economical transition. The recommended shapes for entrance, contraction or expansion and exit transitions for pressure tunnels are given in **3.2** to **3.4**. However, for partly flowing tunnels the methods of design shall be the same as for open channel transition.

3.2 Entrance — To minimize head losses and to avoid zones where cavitation pressures may develop, the entrance to a pressure tunnel shall be streamlined to provide gradual and smooth changes in flow. To obtain best inlet efficiency the shape of entrance should simulate that of a jet discharging into air and should guide and support the jet with minimum interference until it is contracted to the tunnel dimensions. If the entrance curve is too sharp or too short, subatmospheric pressure areas which may induce cavitation, will develop. A bellmouth entrance which conforms to or slightly encroaches upon free jet profile will provide the best entrance shape.

3.2.1 For a circular tunnel the bellmouth shape may be approximated by an elliptical entrance curve represented by the following equation :

$$\frac{x^2}{(0{\cdot}5D)^2}+\frac{y^2}{(0{\cdot}15D)^2}=1$$

where x and y are co-ordinates and D is the diameter of the tunnel at the end of entrance transition. The x-axis of the elliptical entrance is parallel to and at a distance of 0·65 D from the tunnel centre line; y-axis is normal to the tunnel centre line and 0·5 D downstream from the entrance face.

3.2.2 The jet issuing from a square or rectangular opening is not as easily defined as one issuing from a circular opening; the top and bottom curves may differ from the side curves both in length and curvature. Consequently, it is more difficult to determine a transition which will eliminate subatmospheric pressures. An elliptical curved entrance which will tend to minimize the negative pressure effects may be defined by the following equation :

$$\frac{x^2}{D^2} + \frac{y^2}{(0{\cdot}33\ D)^2} = 1$$

where D is the vertical height of the tunnel for defining the top and bottom curves, and also is the horizontal width of the tunnel for defining the side curves. The major and minor axes are positioned similar to those indicated for the circular bellmouth in **3.2.1**.

3.2.2.1 For a rectangular entrance with the bottom placed even with the upstream floor and with curved guide piers at each side of the entrance openings, both the bottom and side contractions will be suppressed and a sharper contraction will take place at the top of the opening. For this condition the top contraction curve may be defined by the following equation :

$$\frac{x^2}{D^2} + \frac{y^2}{(0{\cdot}67\ D)^2} = 1$$

where D is the vertical height of the tunnel downstream from the entrance.

3.3 Contraction and Expansion — To minimize head losses and to avoid cavitation tendencies along the tunnel surfaces, contraction and expansion transitions to and from gate control sections in a tunnel should be gradual. For contractions, the maximum convergent angle should not exceed that indicated by the relationship :

$$\tan \alpha = \frac{1}{U}$$

where

α = angle of the tunnel wall surfaces with respect to its centre line,

U = arbitrary parameter $\frac{v}{\sqrt{gD}}$,

v and D = average of the velocities and diameters at the beginning and end of the transition, and

g = acceleration due to gravity.

3.3.1 Expansion should be more gradual than contraction because of the danger of cavitation where sharp changes in the side walls occur. Furthermore, head loss coefficients for expansions increase rapidly after the angle α exceeds about 10°. Expansion should be based on the following relationship :

$$\tan \alpha = \frac{1}{2U}$$

The notations are the same as for equation given in **3.3**. For pressure tunnels, the angle α may not normally exceed 10°.

3.4 Exit — When a circular tunnel flowing partly full empties into a chute, the transition from the circular section to one with a flat bottom may be made in the open channel downstream from the tunnel portal, or it may be made within the tunnel so that the bottom will be flat at the portal section. Ordinarily, the transition should be made by gradually decreasing the circular quadrants from full radius at the upstream end of the transition to zero at the downstream end. For usual installations the length of the transition can be related to the exit velocity. An empirical rule which may be used to design a satisfactory transition for velocities up to 6 m/s is as follows:

$$L = \frac{2\,v\,D}{3}$$

where

L = length of transition in m,
v = exit velocity in m/s, and
D = tunnel diameter in m.

NOTE — For velocities higher than 6 m/s and depths greater than 5 m hydraulic model studies are essential.

4. PRESSURE FLOW LOSSES

4.1 Friction Losses — Friction factors for estimating the friction losses shall be based on actual field observations. For tunnels flowing full, friction loss may be computed by the use of the formula given in **4.1.1** and **4.1.2**.

4.1.1 *Manning's Formula* — The formula is given below :

$$v = \frac{R^{\frac{2}{3}}\, S^{\frac{1}{2}}}{n}$$

where

v = velocity in m/s,
R = hydraulic radius $\left(\frac{\text{area}}{\text{wetted perimeter}}\right)$ in m,
S = slope of energy gradient, and
n = roughness coefficient or rugosity coefficient.

4.1.1.1 For concrete lined tunnels the value of rugosity coefficient n varies from 0·012 to 0·018.

4.1.1.2 The value of rugosity coefficient n for use in the Manning's formula for an unlined tunnel depends on the nature of the rock and the quality of trimming, and is possibly influenced by the amount and distribution of overbreak. Recommended values of n for various rock surface conditions are given below:

Surface Characteristic	*Value of 'n'*	
	Min	*Max*
Very rough	0·04	0·06
Surface trimmed	0·025	0·035
Surface trimmed and invert concreted	0·020	0·030

NOTE — In a number of unlined tunnels the roughness has been experimentally determined by measuring discharges and friction losses or aerodynamically, data about which are given in Appendix A which may be used for design purpose assuming the effective area and overbreak.

4.1.2 *Darcy Waisbach Formula* — The formula is given below:

$$h_f = \frac{f L}{D} \times \frac{v^2}{2g}$$

where

h_f = friction headloss in m,
f = friction coefficient,
L = the length of the tunnel in m,
D = diameter of the tunnel in m,
v = velocity of flow in the tunnel in m/s, and
g = acceleration due to gravity in m/s^2.

NOTE — The formula given above is superior to the other empirical formulae, such as Bazin, Rehbock and Williams and Hazen because the friction factor f is dimensionless and no fractional powers are involved. The friction coefficient depends on the Raynolds number and the relative roughness, $\frac{K_s}{D}$ where K_s is the equivalent sand grain roughness.

4.1.2.1 For lined tunnels the value of f shall be computed in accordance with IS : 2951 (Part I)-1965*. The values of Ks, the equivalent sand grain roughness for concrete, may be adopted as below:

*Recommendations for estimation of flow of liquids in closed conduits: Part I Head loss in straight pipes due to frictional resistance.

Surface Characteristics	*Value of K_s mm*
Concrete Lining : Unusually rough Rough wood form work Erosion of poor concrete Poor alignment of joints	0·6 to 6·0
Rough Eroded by sharp materials in transit Marks visible from wooden forms Spalling of laitance	0·4 to 0·6
Granular Wood floated or brushed surface in good condition—good joints	0·18 to 0·4
New or fairly new—smooth concrete Steel forms—average workmanship Noticeable air voids on surface-smooth joints	0·06 to 0·18
New—unusually smooth concrete steel forms —first class workmanship Smooth joints	0·015 to 0·06

NOTE — The value of K_s for steel shall be taken from IS : 2951 (Part I)-1965*.

4.1.2.2 For unlined tunnels the value of f depends on the variation in cross-sectional area obtained in the field as well as the direction of driving the tunnel. Tests in, mostly, granite indicate that the friction loss may be estimated by measuring cross-sectional areas at intervals and determining the value of f by the following formula :

$$f = 0{\cdot}002\,57\,\delta$$

where

$$\delta = \frac{A_{99} - A_1}{A_1} \times 100$$

A_{99} = area corresponding to 99 percent frequency, and

A_1 = area corresponding to 1 percent frequency.

4.1.2.3 For tunnels of non-circular cross-section the diameter D in **4.1.2** shall be replaced by $4R$, where R is the hydraulic mean radius, thus reading as follows:

$$h_f = \frac{f L v^2}{8gR}$$

*Recommendations for estimation of flow of liquids in closed conduits: Part I Head loss in straight pipes due to frictional resistance.

4.1.3 For tunnels flowing partly full the head loss in friction shall be computed by the method specified in IS : 4745-1968*.

4.2 Trash Rack Losses — Trash rack structure which consists of widely spaced structural members without rack bars will cause very little head loss and trash rack losses in such a case may be neglected in computing tunnel losses. When the trash rack consists of a rack of bars, the loss will depend on bar thickness, depth and spacing and shall be obtained from the following formula :

$$h_t = K_t \frac{v^2}{2g}$$

where

h_t = trash rack head loss,

K_t = loss coefficient for trash rack

$= 1{\cdot}45 - 0{\cdot}45 \frac{a_n}{a_t} - \left[\frac{a_n}{a_t}\right]^2,$

a_n = net area through trash rack bars,

a_t = gross area of the vent (racks and supports),

v = velocity in net area, and

g = acceleration due to gravity.

4.2.1 Where maximum loss values are desired, 50 percent of the rack area shall be considered clogged. This will result in twice the velocity through the trash rack. For minimum trash rack losses, the openings may not be considered clogged when computing the loss coefficient or the loss may be neglected entirely.

4.3 Entrance Losses — Entrance loss shall be computed by the following equation :

$$h_e = K_e \frac{v^2}{2g}$$

where

h_e = head loss at entrance,

K_e = loss coefficient for entrance,

v = velocity, and

g = acceleration due to gravity.

4.3.1 Values of loss coefficient K_e for various types of entrances shall be assumed to be as given in Table 1.

4.4 Transition Losses — Head loss in gradual contractions or expansions in a tunnel may be considered in relation to the increase or decrease in velocity head and will vary according to the rate of change of area and

*Code of practice for design of cross-section of lined canals.

TABLE 1 LOSS COEFFICIENT FOR TUNNEL ENTRANCES

(*Clause* 4.3.1)

Sl No.	Type of Entrance	Loss Coefficient for Entrance, K_e		
		Maximum	Minimum	Average
(1)	(2)	(3)	(4)	(5)
i)	Gate in thin wall-unsuppressed contraction	1·80	1·00	1·50
ii)	Gate in thin wall-bottom and sides suppressed	1·20	0·50	1·00
iii)	Gate in thin wall-corners rounded	1·00	0·10	0·50
iv)	Square-cornered entrances	0·70	0·40	0·50
v)	Slightly rounded entrances	0·60	0·18	0·25
vi)	Fully rounded entrances $\frac{r}{D} \geqslant 0{\cdot}15$	0·27	0·08	0·10
vii)	Circular bellmouth entrances	0·10	0·04	0·05
viii)	Square bellmouth entrances	0·20	0·07	0·16
ix)	Inward projecting entrances	0·93	0·56	0·80

length of transition. These losses shall be assumed as specified in IS : 2951 (Part II)-1965*.

4.4.1 For gradual contractions, loss of head h_c, shall be computed by the following equation :

$$h_c = K_c \left[\frac{v_2^2}{2g} - \frac{v_1^2}{2g}\right]$$

where

K_c = loss coefficient for contraction,
v_2 = velocity in contracted section,
v_1 = velocity in normal section, and
g = acceleration due to gravity.

4.4.1.1 The value of loss coefficient K, shall be assumed to vary from 0·1 for gradual contractions to 0·5 for abrupt contractions. Where flare angle does not exceed those specified in **3.3** the loss coefficient shall be assumed to be 0·1. For greater flare angles the loss coefficient shall be assumed to vary in straight line relationship to a maximum of 0·5 for a right angle contraction.

*Recommendations for estimation of flow of liquids in closed conduits: Part II Head loss in valves and fittings.

4.5 Bend and Junction Loss — Head loss at bends and junctions shall be assumed as given in IS : 2951 (Part II)-1965*.

4.6 Gate Loss in Pressure Tunnels — No gate loss need be assumed if the velocity of flow is less than 1 m/s. Where a gate is mounted at either the upstream or downstream side of a thin head wall such that the sides and bottom of jet are suppressed and the top is contracted, loss coefficients given in item (*ii*) of Table 1 shall be taken. Where a gate is so mounted in a tunnel that the floor, sides and the roof, both upstream and downstream, are continuous with the gate openings, only the losses due to the slot shall be considered as given below assuming the value of loss coefficient K_g not exceeding 0·10 :

$$h_g = K_g \frac{v^2}{2g}$$

where

h_g = gate head loss,
K_g = loss coefficient for gate,
v = velocity, and
g = acceleration due to gravity.

4.6.1 For partly open gates the coefficient of loss will depend on top contraction; for smaller openings it will approach a value of 1·0 as indicated in item (*ii*) of Table 1.

4.6.2 For wide open gates value of loss coefficient shall be assumed to be 0·19. Similar to partly open gates, value of the loss coefficient will increase for smaller gate openings.

4.7 Exit Losses — Where no recovery of velocity head will occur, such as where the release from a pressure tunnel discharges freely, or is submerged or supported on a downstream floor, velocity head loss coefficient K_{ex} shall be assumed to be equal to 1·0. Head loss at exit shall be computed by the following equation:

$$h_{ex} = K_{ex} \frac{v^2}{2g}$$

where

h_{ex} = exit head loss,
K_{ex} = loss coefficient for exit,
v = exit velocity, and
g = acceleration due to gravity.

4.7.1 Where a diverging tube is provided at the end of tunnel, recovery of a portion of the velocity head will be obtained if the tube expands gradually

*Recommendations for estimation of flow of liquids in closed conduits: Part II Head loss in valves and fittings.

and if the end of the tube is submerged, the loss coefficient K_{ex} shall be reduced from the value of 1·0 by the degree of head recovery.

5. VELOCITY

5.1 Average permissible velocity in a concrete lined tunnel may be about 6 m/s. For steel lined tunnels velocities as dictated by economic studies shall be chosen. In case of river diversion tunnels and tunnel spillways there may be no such limitations on the maximum permissible velocity, however, the lining and its surface shall be designed to withstand the velocities which will occur.

5.1.1 Permissible velocities in tunnels of different surfaces (unlined, concrete lined, steel lined) also depend upon the sediment load carried by the water. Where water carrying abrasive material in suspension and as bed load is to be conveyed the permissible velocity should be reduced. A recommended velocity is 2·5 m/s.

6. AIR LOCKING AND REMEDIAL MEASURE

6.1 General — The presence of air in a pressure tunnel can be a source of grave nuisance as given below:

a) The localization of an air pocket at the high point in a tunnel or at a change in slope which occasions a marked loss of head and diminution of discharge.

b) The slipping of a pocket of air in a tunnel and its rapid elimination by an air vent can provoke a water hammer by reason of the impact between two water columns.

c) The supply of emulsified water to a turbine affects its operation by a drop in output and efficiency thus adversely affecting the operation of generator. The presence of air in a Pelton nozzle can be the cause of water hammer shocks. Admission of air to a pump may occasion loss of priming.

d) If the velocity exceeds a certain limit air would be entrained causing bulking.

6.2 Source of Air — Air may enter and accumulate in a tunnel by the following means:

a) During filling, air may be trapped along the crown at high points or at changes in cross-sectional size or shape;

b) Air may be entrained at intake either by vortex action or by means of hydraulic jump associated with a partial gate opening; and

c) Air dissolved in the flowing water may come out of solution as a result of decrease in pressure along the tunnel.

6.3 Remedial Measures — The following steps are recommended to prevent the entry of air in a tunnel:

a) Shallow intakes are likely to induce air being sucked in. Through-

out the tunnel the velocity should either remain constant or increase towards the outlet end. It should be checked that at no point on the tunnel section negative pressures are developed.

b) Vortices that threaten to supply air to a tunnel should be avoided, however, if inevitable they should be suppressed by floating baffles, hoods or similar devices.

c) Partial gate openings that result in hydraulic jumps should be avoided.

d) Traps or pockets along the crown should be avoided.

6.3.1 In some cases, such as secondary feeder shafts supplying a main tunnel air entrance may appear inevitable. In such cases de-aeration chamber with enlarged area should be provided so that no air enters the main tunnel. Where possible it is advisable that such intakes are checked on hydraulic models to ensure no entrance of air.

APPENDIX A

(*Note under Clause* 4.1.1.2)

VALUES OF *n* FOR EXISTING TUNNELS

Sl No.	Type of Rock	Theoretical		Actual Effective		Overbreak		Manning's n
		Area (A_t)	Hydraulic Radius (R)	Area (A_e)	Hydraulic Radius (R_e)	$\frac{A_e}{A_t}$	Percent (Volume)	
		m²	m	m²	m			
i)	Granite-gneiss	30	1·46	33·8	1·54	1·128	12·7	0·035 4*
ii)	Granite-gneiss	50	1·85	57·4	2·09	1·15	14·8	0·034 3*
iii)	Granite-gneiss	50	1·85	61·5	2·16	1·23	23·0	0·030 0*
iv)	Granite-gneiss	30	1·45	35·9	1·62	1·20	19·6	0·038 4*
v)	Gneiss-granite with some diabase	60	2·00	64·0	—	1·07	6·6	0·027 0*
vi)	Vein-gneiss	5	0·59	6·6	0·71	1·32	32·0	0·033 9*
vii)	Arkose sand-stone	28·7	1·53	34·9	1·64	1·21	—	0·038 †
viii)	Arkose sand-stone	35·4	1·68	40·1	1·74	1·13	—	0·038 †
ix)	Upper sillurian slate horizontally stratified	105	2·74	114·3	2·88	1·088	8·9	0·029 2*
x)	Black slate with granite intrusions	70	2·24	80·5	2·42	1·15	15·1	0·043 7*

*Calculated from the length of tunnel, the effective area and the hydraulic radius and he observed friction head.

†Calculated from the length of tunnel, from actual area of tunnel and hydraulic radius of quivalent circle.

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Telephones : 3 31 01 31, 3 31 13 75 Telegrams : Manaksanstha (Common to all Offices)

Regional Offices :	*Telephone*
*Western : Manakalaya, E9 MIDC, Marol, Andheri (East), BOMBAY 400093	6 32 92 95
†Eastern : 1/14 C. I. T. Scheme VII M. V. I. P. Road, Maniktola, CALCUTTA 700054	36 24 99
Northern : SCO 445-446, Sector 35-C CHANDIGARH 160036	2 18 43 3 16 41
Southern : C. I. T. Campus, MADRAS 600113	41 24 42 41 25 19 41 29 16
Branch Offices :	
Pushpak,' Nurmohamed Shaikh Marg, Khanpur, AHMADABAD 380001	2 63 48 2 63 49
'F' Block, Unity Bldg, Narasimharaja Square, BANGALORE 560002	22 48 05
Gangotri Complex, 5th Floor, Bhadbhada Road, T. T. Nagar, BHOPAL 462003	6 27 16
Plot No. 82/83, Lewis Road, BHUBANESHWAR 751002	5 36 27
53/5 Ward No. 29, R. G. Barua Road, 5th Byelane, GUWAHATI 781003	—
5-8-56C L. N. Gupta Marg, (Nampally Station Road), HYDERABAD 500001	22 10 83
R14 Yudhister Marg, C Scheme, JAIPUR 302005	6 34 71 6 98 32
117/418B Sarvodaya Nagar, KANPUR 208005	21 68 76 21 82 92
Patliputra Industrial Estate, PATNA 800013	6 23 05
Hantex Bldg (2nd Floor), Rly Station Road, TRIVANDRUM 695001	52 27
Inspection Office (With Sale Point):	
Institution of Engineers (India) Building, 1332 Shivaji Nagar, PUNE 410005	5 24 35

*Sales Office in Bombay is at Novelty Chambers, Grant Road, Bombay 400007 — 89 65 28

†Sales Office in Calcutta is at 5 Chowringhee Approach, P. O. Princep Street, Calcutta 700072 — 27 68 00

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